Determination of the structure of the high energy hadron elastic scattering amplitude at small angles

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Abstract

A new method for the determination of the real part of the elastic scattering amplitude is examined for high energy proton-proton and proton-nuclei elastic scattering at small momentum transfer. This method allows us to decrease the number of model assumptions, to obtain the real part in a narrow region of momentum transfer and to test different models for hadron-nuclei scattering.

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1 Introduction

The investigation of the structure of the hadron scattering amplitude is an important task both for theory and experiment. PQCD cannot calculate neither the value of the scattering amplitude, nor its phase or its energy dependence in the soft diffraction range. A deeper understanding of the way that such fundamental relation as integral dispersion and local dispersion relations work requires the knowledge of the structure of the scattering amplitude with high accuracy [1]. It was shown in [2] that the knowledge of the behavior of ρ - the ratio of the real to the imaginary part of the spin-non-flip amplitude - can be used for checking local quantum field theory (QFT) already in the LHC energy region.

A large number of experimental and theoretical studies of high-energy elastic proton-proton and proton-antiproton scattering at small angles gives a rich information about this process, and allows to narrow the circle of examined models and to point to a number of difficult problems which are not yet solved entirely. This concerns especially the energy dependence of a number of characteristics of these reactions and the contribution of the odderon.

Many of these questions are connected with the dependence with s and t of the spin-non-flip phase of hadron-hadron scattering. Most of the models define the real part of the scattering amplitude phenomenologically. Some models use the local dispersion relations and the hypothesis of geometrical scaling. As is well known, using some simplifying assumption, the information about the phase of the scattering amplitude can be obtained from the experimental data at small momentum transfers where the interference of the electromagnetic and hadronic amplitudes takes place. On the whole, the obtained information confirms the local dispersion relations. It was shown in [3] that a self-consistent description of the experimental data in the energy range of the ISR and the SPS can be obtained in the case of a rapidly changing phase when the real part of the scattering amplitude grows quickly at small t and becomes dominant.

Now the physics of high-energy nuclei scattering is developing quickly and the knowledge of the structure of the elastic proton-nuclei and nucleus-nucleus scattering

is needed to discriminate between different models describing high-energy nuclei interactions. This is especially important in view of the development of the QCD approach to the high-energy nuclei interaction [5].

The standard procedure to extract the magnitude of the real part includes a fit to the experimental data taking the magnitude of the total hadronic cross section, the slope, ρ, and, sometimes the normalization coefficient corresponding to luminosity as free parameters:

$$\sum_{i}^{k} \frac{(nd\sigma^{exp}/dt(t=t_i) - d\sigma/dt(t=t_i))^2}{\Delta^2_{exp,i}} \tag{1}$$

where $d\sigma^{exp}/dt(t=t_i)$ is the differential cross sections at point t_i, with the statistical error $\Delta_{exp,i}$ extracted from the measured dN/dt using, for example, the value of the luminosity, n is a fitted normalization parameter. This procedure requires a sufficiently wide interval of t and a large number of experimental points.

The theoretical representation of the differential cross-sections is

$$\frac{d\sigma}{dt} \ = 2\pi[|\Phi_1|^2 + |\Phi_2|^2 + |\Phi_3|^2 + |\Phi_4|^2 + 4|\Phi_5|^2] \ , \tag{2}$$

where Φ_1 and Phi_3 are the spin non-flip amplitudes. The total helicity amplitudes can be written as a sum of nuclear $\Phi_i^h(s,t)$ and electromagnetic $\Phi_i^e(s,t)$ amplitudes :

$$\Phi_i(s,t) = \Phi_i^h(s,t) + e^{i\alpha\varphi}\Phi_i^e(t) \ , \tag{3}$$

where $\Phi_i^e(t)$ are the leading terms at high energies for the one-photon amplitudes as defined, for example, in [4] and α is the fine-structure constant. The common phase φ is

$$\varphi = \pm[\gamma + \log{(B(s,t)|t|/2)} + \nu_1 + \nu_2], \tag{4}$$

where the upper(low) sign related to the $p\bar{p}(pp)$ scattering, and $B(s,t)$ is the slope of the nuclear amplitude, and ν_1 and ν_2 are small correction terms defining the behavior of the Coulomb-hadron phase at small momentum transfers (see, [6] or more recently [7]). At very small t and fixed s, these electromagnetic amplitudes are such that $\Phi_1^e(t) = \Phi_3^e(t) \sim \alpha/t$, $\Phi_2^e(t) = -\Phi_4^e(t) \sim \alpha \cdot \text{const.}$, $\Phi_5^e(t) \sim -\alpha/\sqrt{|t|}$. We

assume, as usual, that at high energies and small angles the double-flip amplitudes are small with respect to the spin-nonflip one and that spin-nonflip amplitudes are approximately equal. Consequently, the observables are determined by two spin non-flip amplitudes: $F(s,t) = \Phi_1(s,t) + \Phi_3(s,t) = F_N + F_C \ \exp(i\alpha\varphi)$.

In the case of high-energy hadron scattering, we can neglect the contribution of the spin-flip amplitude at small momentum transfer in the differential cross section and write in the $O(\alpha)$ approximation :

$$d\sigma/dt = \pi |e^{i\alpha\varphi} F_C + F_N|^2 = \pi \ [(F_C + ReF_N)^2 + (\alpha\varphi F_C + ImF_N)^2] \,. \tag{5}$$

In the standard fitting procedure, this equation takes the form:

$$\begin{aligned} d\sigma/dt \ &= \pi[(F_C(t))^2 + (\rho(s,t)^2 + 1)(ImF_N(s,t))^2) \\ &\quad + 2(\rho(s,t) + \alpha\varphi(t))F_C(t)ImF_N(s,t)], \end{aligned} \tag{6}$$

where $F_C(t) = \mp 2\alpha G^2/|t|$ is the Coulomb amplitude (the upper sign is for pp, the lower sign is for $p\bar{p}$) and $G^2(t)$ is the proton electromagnetic form factor squared; $Re\ F_N(s,t)$ and $Im\ F_N(s,t)$ are the real and imaginary parts of the nuclear amplitude; $\rho(s,t) = Re\ F_N(s,t)/Im\ F_N(s,t)$. The formula (6) is used for the fit of experimental data determining the Coulomb and hadron amplitudes and the Coulomb-hadron phase to obtain the value of $\rho(s,t)$.

2 The real part of the spin-non-flip amplitude of the pp scattering

Numerous discussions of the function $\rho(s,t)$ measured by the UA4 [8] and UA4/2 [9] Collaborations at $\sqrt{s} = 541$ GeV have revealed the ambiguity in the definition of this semi-theoretical parameter [10], and, as a result, it has been shown that one has some trouble in extracting, from experiment, the total cross sections and the value of the forward ($t = 0$) real part of the scattering amplitudes [11]. In fact, the problem is that we have at our disposal only one observable $d\sigma/dt$ for two unknowns, the real and imaginary parts of $F_N(s,t)$. So, we need either some additional experimental

information which would allow us to determine independently the real and imaginary parts of the spin non-flip hadron elastic scattering amplitude or some new ways to determine the magnitude of the phase of the scattering amplitude with minimum theoretical assumptions. One of the most important points in the definition of the real part of the scattering amplitude is the knowledge of the normalization coefficient and of the magnitude of $\sigma_{tot}(s)$.

To obtain the magnitude of $ReF_N(s,t)$, we fit the differential cross sections taking into account the value of σ_{tot} either from another experiment, to decrease the errors, as made by the UA4/2 Collaboration, or as a free parameter, as done in [10]. If one does not take the normalization coefficient as a free parameter in the fitting procedure, its definition requires the knowledge of the behavior of the imaginary and real parts of the scattering amplitude in the range of small momentum transfer, of the magnitude of $\sigma_{tot}(s)$ and of $\rho(s,t)$.

Let us note three points. First, we should take into account the errors on $\sigma_{tot}(s)$. Second, this method implies that the slope of imaginary part of the scattering amplitude is equal to the slope of its real part in the examined range of momentum transfer, and, for the best fit, one should take the interval of momentum transfer sufficiently large. Third, the magnitude of $\rho(s,t)$ thus obtained corresponds to the whole interval of momentum transfer .

In this article, we briefly describe new procedures simplifying the determination of elastic scattering amplitude parameters.

From equation (5), one can obtain an equation for $ReF_N(s,t)$ for every experimental point i:

$$\begin{aligned} &ReF_N(s,t_i) = -F_C(t) \\ &\pm[(1+\delta)/\pi d\sigma^{exp}/dt(t=t_i) - (\alpha\varphi F_C(t_i) + ImF_N(s,t_i))^2]^{1/2}, \end{aligned} \tag{7}$$

where

$$\delta = \epsilon/N, . \tag{8}$$

N in eq. (8) being the normalization constant in a well-defined experiment by using a particular method of obtaining the normalization (for example, by luminocity) and

ϵ - the inevitable error on N due to the use of a particular method. For example, in method of luminosity it reflects the error in the mesuare of luminosity. Therefore n from eq. (1) is given by

$$n = 1 + \delta, \tag{9}$$

We define the imaginary part of the scattering amplitude *via* the usual exponential approximation in the small t-region

$$ImF_N(s,t) = \sigma_{tot}/(0.389 \cdot 4\pi) \exp(Bt/2), \tag{10}$$

where 0.389 is the usual converting dimensional factor for expresing σ_{tot} in mb.

It is evident from (7) that the determination of the real part depends on δ, σ_{tot}, and B, the magnitude of σ_{tot} depending itself on δ. Equation (7) shows the possibility to calculate the real part at every separate point t_i if the imaginary part of the scattering amplitude and δ are fixed, and to check the exponential form of the obtained real part of the scattering amplitude (see [12]).

Let us define the sum of the real parts of the hadron and Coulomb amplitudes as $\sqrt{\Delta_R}$, so we can write:

$$\Delta_R^{th.}(s,t_i) = [ReF_N(s,t_i) + F_C(t)]^2. \tag{11}$$

Using the experimental data on the differential cross sections we obtain:

$$\begin{aligned} \Delta_R(s,t_i) &= \Delta_R^{exp.}(s,t_i) = \\ (1+\delta)/\pi \; d\sigma^{exp.}/dt(t &= t_i) - (\alpha\varphi F_C(t_i) + ImF_N(s,t_i))^2 \end{aligned} \tag{12}$$

This formula has a significant property for the proton-proton scattering at very high energy, but, of course, non-asymptotic, is sufficiently large and opposite in sign relative to the Coulomb amplitude and for proton-antiproton scattering at low energy where the real part of the hadron amplitude is negative. Let us put the representation of the differential cross sections, using eg.(6), in eq. (7), taking into account that we do not know exactly the normalization of the differential cross sections. So, we get

$$\begin{aligned} &\Delta_R(s,t_i) = (1+\delta)(ReF_N(s,t_i) + F_C(t))^2 \\ &+\delta(\alpha\varphi F_C(t_i) + ImF_N(s,t_i))^2. \end{aligned} \tag{13}$$

As expected, in the standard picture of high-energy hadron scattering at small momentum transfer, the real part of $F_N(s,t)$ is positive and non-negligible in the region 50 GeV $\leq \sqrt{s} \leq 20$ TeV. The experiments at $\sqrt{s} \simeq 50$ GeV for proton-proton and at 541 GeV for proton-antiproton scattering support this picture. Hence, using the experimental data of the differential cross sections on high energy pp-scattering at some energy s_j and the the imaginary part of the hadron amplitude, we can calculate the value $\Delta_R(s_j,t_i)$.

Let us examine this expression for the pp scattering amplitude at energies above $\sqrt{s} = 500$ GeV. In order to do this, let us make a gedanken experiment and calculate $d\sigma/dt_i$ at some high energy. For that let us take the hadron amplitude in the exponentially form with fixed parameters ($\rho = 0.15$ and $\sigma_{tot} = 63$ mb) and calculate the differential cross sections in some number of points of t. These values will be considered as "experimental" points at $d\sigma_i/dt$ of the differential cross section at t_i. In this case, we exactly know the all parameters of hadron amplitude from beginning and can check the our final result by compare it with the input parameters.

For pp scattering at high energies, equation (13) induce a remarkable property: the real part of the Coulomb pp scattering amplitude is negative and exceeds the size of $F_N(s,t)$ at $t \to 0$, but it has a large slope. As the real part of the hadron amplitude is positive at high energies, it is obvious that Δ_R has a minimum at a position in t independent of n and of σ_{tot}, as shown in Fig. 1.

The position of the minimum gives us the value $t = t_{min}$ where $ReF_N = -F_C$. As we know the Coulomb amplitude, we can estimate the real part of the pp scattering amplitude at this point. Note that all other methods give us the real part only in a rather wide interval of momentum transfer. The true normalization coefficient and the true value of σ_{tot} will correspond to a zero in $\Delta_R(s,t)$ at the point t_{min}. But if the normalization coefficient is not the true one, the minimum will be or above or below zero, but practically at the same point t_{min}. So, the size of Δ_R also tests the validity of the determination of the normalization coefficient and of σ_{tot}.

This method works only in the case of positive real part of the hadron amplitude and it is especially efficient in the case of large ρ. So, this method is interesting for

the experiments which will be done at RHIC and for the future TOTEM experiment at LHC.

In spite of the fact that at ISR energies we have small $\rho(s, t \approx 0)$ and few experimental points, let us try to examine one experiment, for example, at $\sqrt{s} =$ 52.8 GeV. This analysis is shown in Fig.2. One can see that in this case the minimum is sufficiently large, and $-t_{min} = (3.3 \pm 0.1) 10^{-2}$ GeV^2. The corresponding real part is equal to 0.38 ± 0.014 mb$^{1/2}$/GeV. Our analysis gives $\rho(t_{min}) = 0.054 \pm 0.003$, as compared with $\rho(t = 0) = 0.077 \pm 0.009$ as given in [13].

Now let us see what we can obtain in the future experiment on the proton-proton elastic scattering at maximum energy of RHIC. For that we can simulate the experimental data on the differential cross sections by calculating with some model for the imaginary and real parts of the hadron amplitude with definitely parameters σ_{tot}, B, ρ as we made above. After that we have to taking account the possible statistic errors expected in future experiments. Namely we calculate the deviation from the theoretical values of the differential cross sections (in units of error bias) at examined point of t_i by using a Gaussian random procedure to calculate the probability of the deviation. After that we change our theoretical differential cross section on this deviation. In result we obtain the "simulated experimental" data with some "experimental" errors. These "experimental" data will have the Gaussian distribution from the theoretical curve. As a result, we can simulate the future experimental data for the differential cross sections, for example, with the possible ρ values 0.135 or 0.175. Then we can get the values of Δ_R from these gedanken " experimental" data with correspounding statistical errors. These values are shown in Figs. 3a and 3b and we can note the difference between the two respective models for the "data" corresponding to two different values of ρ. The pure theoretical representation of Δ_R with $\rho = 0$ and the same values of ρ as above are also shown.

There are other two interesting features: the magnitude and the position of the second maximum. It is easy to connect the size of the maximum with the magnitude of the real part of the scattering amplitude. Let us consider the t-region very near the minimum or the maximum in Δ_R. In this region, we can approximate the t-

dependence of the electromagnetic form factor by an exponential of slope D and $ReF_N(s,t)$ by an exponential with slope B_r. We then equate the derivative of Δ_R to zero:

$$\frac{d}{dt}[\Delta_R] = \frac{d}{dt}[h_1^2 \frac{1}{t^2} e^{Dt} + 2h_1 h_2 \frac{1}{t} e^{Dt/2} e^{B_r t/2} + h_2^2 e^{B_r t}] = 0, \tag{14}$$

where h_1 and h_2 are some electromagnetic and hadronic constants.

Therefore, at $-t = t_{max}$, where t_{max} is corresponding to the second maximum of Δ_R, we get

$$\begin{aligned} & 2h_1^2 e^{-Dt_{max}} + h_1^2 D t_{max} e^{-Dt_{max}} - 2h_1 h_2 \frac{D+B_r}{2} t_{max}^2 e^{-Dt_{max}/2} e^{-B_r t_{max}/2} \\ & -2h_1 h_2 t_{max} e^{-Dt_{max}/2} e^{-B_r t_{max}/2} + h_2^2 t_{max}^3 B_r e^{-B_r t_{max}} = 0. \end{aligned} \tag{15}$$

No term in this equation can be neglected, because in the region of interest all these terms are of the same order of magnitude. As a result, we obtain a simple quadratic equation at $-t = t_{max}$:

$$\frac{ReF_N^2}{ReF_C^2} \frac{B_r t_{max}}{2} + \frac{ReF_N}{ReF_C} (1 + \frac{D+B_r}{2} t_{max}) + \frac{D}{2} t_{max} + 1 = 0. \tag{16}$$

It leads to the simple relation

$$B_r/2 = (1 + \frac{D}{2} t_{max}) \; \frac{-1}{t_{max}} \frac{F_C}{ReF_N}. \tag{17}$$

Remembering the definition of Δ_R, we obtain

$$B_r/2 = (1 + \frac{D}{2} t_{max}) \; \frac{1}{t_{max}} \frac{1}{(1 - \Delta_R^{1/2}/ReF_C)}. \tag{18}$$

So, we can determine the slope of the real part of the hadron elastic scattering amplitude without any fitting procedure in a large interval of momentum transfer.

Note that the point t_{min} is also important for the determination of the real part of the spin-flip amplitude [14]. At that point, some terms in the definition of the analyzing power will be canceled. Together with them from the basic equation the imaginary part of the spin-flip amplitude disappear also. Such reducing representation can be used for the determination of the real part of the hadron spin-flip amplitude at high energy and small angles.

3 The real part of the spin-non-flip amplitude of the pA scattering

It is interesting to apply this new method to proton-nucleus scattering at high energies. The size of the hadron amplitude grows only slightly less then A, the atomic number: for example, $\sigma_{tot}(pp) = 38$ mb and $\sigma_{tot}(p^{12}C) = 335$ mb in the region of 100 GeV. The most important difference in proton-nucleus scattering as compared with pp scattering is that the slope of the differential cross section is very high: $\simeq 70$ GeV^{-2} for this nuclear reaction at 100 GeV. The electromagnetic amplitude grows like Z. Its slope also grows. It is interesting that the simple calculations, which take the hadron amplitude at small momentum transfer in the usual exponential form with a large slope, lead to practically the same results as for proton-proton scattering.

Let us take the Coulomb amplitude for $p^{12}C$ scattering in the form

$$F_C \quad = \quad \frac{2\alpha_{em}\ Z}{t}\ F_{em}^{^{12}C} F_{em1}^{p} F_{em}^{^{12}C} F_{em2}^{p}, \tag{19}$$

where F_{em1}^{p} and F_{em2}^{p} are the electromagnetic form factors of the proton, and $F_{em}^{^{12}C}$ that of ^{12}C. We use

$$F_{em1}^{p} \quad = \quad \frac{4m_p^2 - t(\kappa_p + 1)}{(4m_p^2 - t)(1 - t/0.71)^2}, \tag{20}$$

$$F_{em2}^{p} \quad = \quad \frac{4m_p^2 \kappa_p}{(4m_p^2 - t)(1 - t/0.71)^2}, \tag{21}$$

where m_p is the mass of the proton and κ_p the proton anomalous magnetic moment. We obtain $F_{em}^{^{12}C}$ from the electromagnetic density of the nucleus [15]

$$D(r) = D_0\ \left[1 + \tilde{\alpha}\left(\frac{r}{a}\right)^2\right] e^{-\left(\frac{r}{a}\right)^2}, \tag{22}$$

$\tilde{\alpha} = 1.07$ and $a = 1.7$ fm giving the best description of the data in the small t-region and producing a zero of $F_{em}^{^{12}C}$ at $|t| = 0.130$ GeV^2. We also calculated $F_{em}^{^{12}C}$ by integrating the nuclear form factor as given by a sum of Gaussians [16] and we obtain practically the same result, the zero being now at $|t| = 0.133$ GeV^2.

We take the hadron amplitude in the standard exponential form with the parameters obtained in [17], $\sigma_{tot} = 335$ mb and $B = 62$ GeV^{-2}. The calculations shown in

Fig. 4 for two variants (with $\rho = 0.1$ and $\rho = 0.075$) demonstrate that the minimum is situated approximately in the same t-region as for the minimum in proton-proton scattering. There is also a significant difference in the size of the maximum for these two values of ρ, which is connected with the large slope of proton-nucleus scattering.

Such calculations were also carried out for p^{28}Si reaction. In this case, we determine the electromagnetic form-factor as sum of gaussians in the r-representation [16]. The parameters of the hadron scattering amplitude were chosen near the parameters for $p^{27}Al$ scattering, given by [18]: $\sigma_{tot} = 800$ mb and $B = 120$ GeV^{-2}. The results are shown in Fig.5. It is clear that we obtain a very similar situation, weakly dependent on the specific nucleus.

All previous results were obtained under the assumption that hadron scattering amplitude has the same exponential behavior as the pp scattering amplitude at high energies. Very frequently the Glauber model is used for the description of hadron-nuclei reactions and this model gives a different behavior for the hadron scattering amplitude at small momentum transfer. The slope of the hadron amplitude of the elastic proton-nuclear scattering increases with $|t|$ (see Fig.6), like in "black body" limits. But in pp scattering, the slope is either constant or slightly decreasing with $|t|$ at small momentum transfer region . At low energy a good description was obtained for different nuclear reactions in the framework of Glauber model [19]. Note that proton-proton scattering at low energy is also predicted by the Glauber model to have the same behavior as nuclear reactions at low transfer momentum. In Fig.6, the slopes of the real and imaginary part of the hadron amplitude of $p^{12}C$ elastic scattering calculated in the Glauber model are shown.

The calculations were obtained by the formulas used in Refs. [20] and [21]. It is clear that the real part decreases very fast and changes sign at $-t = 0.06$ GeV^2. Δ_R with $\rho = 0.1$ has a wide minimum in the region $0.025 \leq |t| \leq 0.045$ GeV^2 (see Figs. 8a and 8b). But if we perform such a calculation for $\rho = -0.1$, the ordinary minimum is obtained but is situated at a large value of t. This can be understood from Fig.7, were we show the real parts of the hadron amplitude (for $\rho = \pm 0.1$) and of the Coulomb amplitude. In the region around $|t| \simeq 0.05$ GeV^2 the

slopes of the two amplitudes coincide. A significant cancellation occurs for $\rho = 0.1$. All these results come from the behavior of the slope of the hadron amplitude in the Glauber model. As a result, we obtain a very different behavior of Δ_R in the Glauber model as compared with the exponential behavior. So, the investigation of Δ_R can distinguish different approaches.

4 Conclusion

The precise experimental measurements of dN/dt and the spin correlation parameter A_N at RHIC, as well as, if possible, at the Tevatron, will therefore give us unavailable information on hadron elastic scattering at small t. New phenomena at high energies [22] could be therefore detected without going through the usual arbitrary assumptions (such as the exponential form) concerning the behavior of the hadron elastic scattering amplitude. It is interesting to apply this method to proton-nuclei scattering at high energy, especially at RHIC energies. It gives a unique possibility to investigate the real part of the hadron amplitude in nuclear reactions.

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Captions

FIG.1. Δ_R for pp scattering at $\sqrt{s} = 540$ GeV and with $\sigma_{tot} = 63$ mb, for different n [triangles - the calculations by (12); curves and circles - the calculations by (13)].

FIG.2. Δ_R for pp scattering using the experimental data for $d\sigma/dt$ at $\sqrt{s} = 52.8\ GeV$ [13]. The lines are polynomial fits to the points calculated with experimental data and with different n

FIG.3 (a,b). Δ_R for pp scattering at $\sqrt{s} = 540$ GeV with a) $\rho_1 = 0.135$ and b) $\rho_2 = 0.175$. The solid, dashed, and dotted lines are the theoretical curves calculated by eq. (11) for $\rho_2 = 0.175$, $\rho_1 = 0.135$ and $\rho_0 = 0$ respectively. The points show the Δ_R calculated from the "simulated experimental" data $d\sigma/dt$ for both cases.

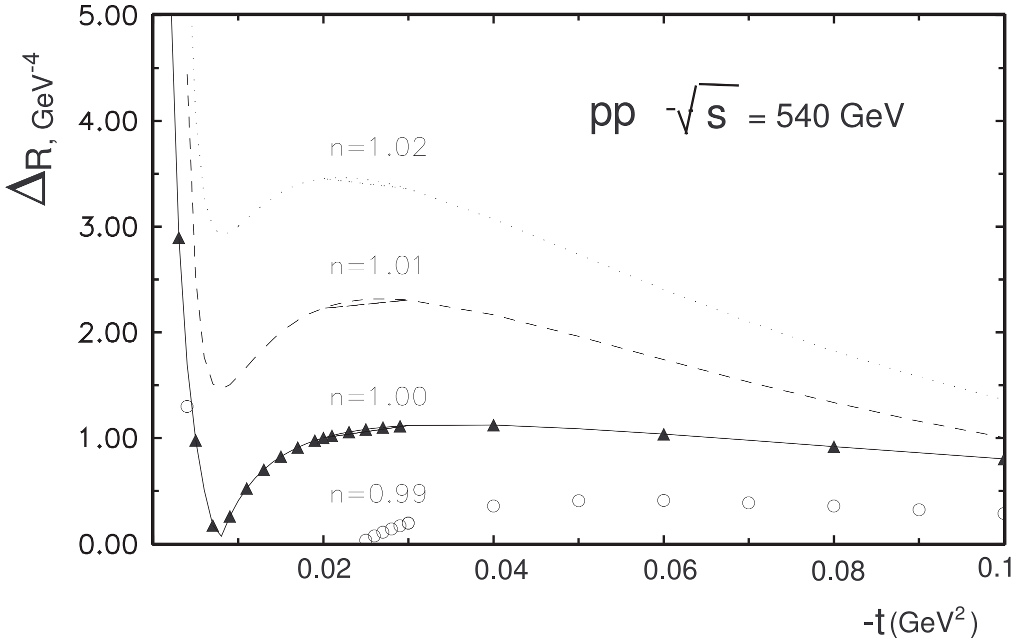
FIG.4. Δ_R for $p^{12}C$ scattering with $\rho = 0.1$ and $\rho = 0.075$ (solid and dashed lines respectively) for the exponential behavior of the hadron amplitude.

FIG.5. Δ_R for $p^{28}Si$ scattering with $\rho = 0.1$ and $\rho = 0.075$ (solid and dashed lines respectively) for an exponential behavior of the hadron amplitude.

FIG.6. The slope B_{gl} of the real (hard line) and imaginary (dashed line) parts of the hadronic amplitude, calculated from the Glauber model for $p^{12}C$ scattering.

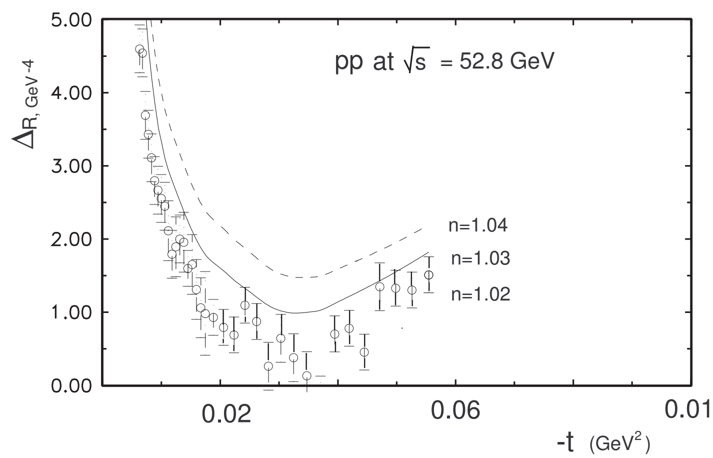
FIG.7. The real part of the electromagnetic amplitude (hard line) and the real part of the hadron amplitude (dashed line) calculated from the Glauber model for $p^{12}C$scattering with $\rho = 0.1$ (long-dashed line) and with $\rho = -0.1$. .

FIG.8 (a,b). Δ_R for $p^{12}C$ scattering with $\rho = 0.1$ and $\rho = -0.1$ (solid and dashed lines respectively) calculated in the framework of the Glauber model, with linear (a) and logarithmic (b) scales.



pp $\sqrt{s}$ = 540 GeV
n=1.02
n=1.01
n=1.00
n=0.99
$\Delta_{R,\ GeV^{-4}}$
-t (GeV^2)
5.00
4.00
3.00
2.00
1.00
0.00
0.02
0.04
0.06
0.08
0.1

Fig.1



pp at $\sqrt{s}$ = 52.8 GeV
n=1.04
n=1.03
n=1.02
$\Delta_{R,\ GeV^{-4}}$
-t (GeV^2)
5.00
4.00
3.00
2.00
1.00
0.00
0.02
0.06
0.01

Fig. 2

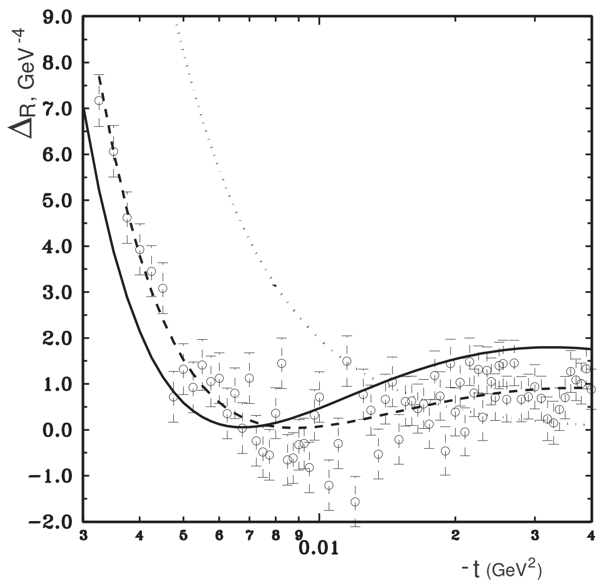


Fig.3 a

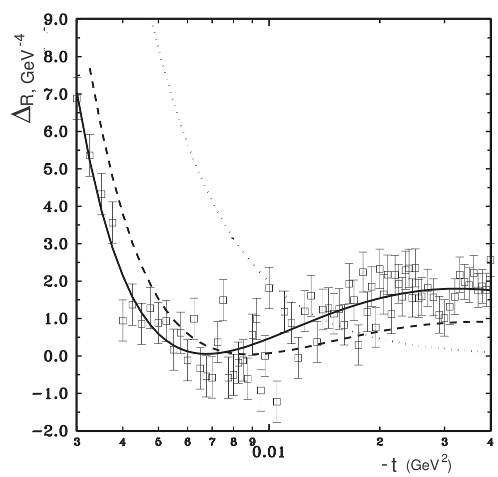
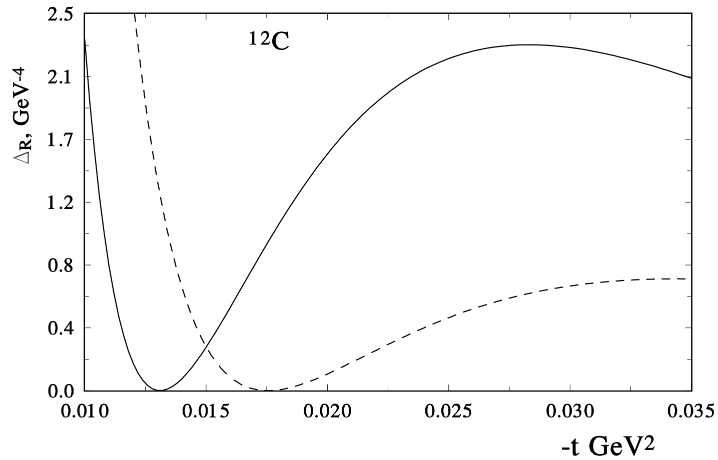
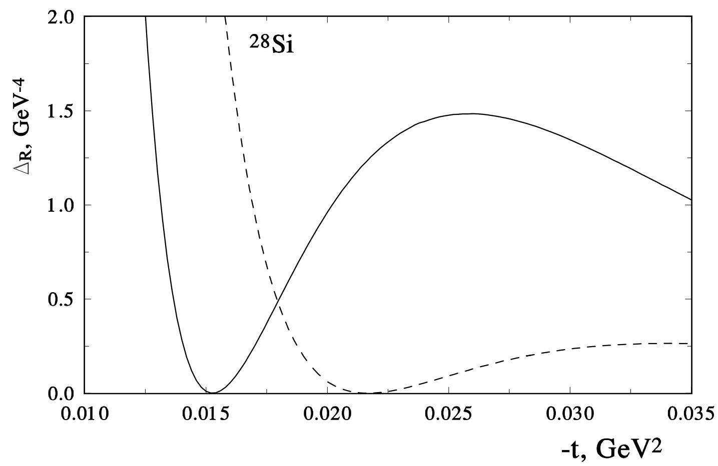


Fig.3 b



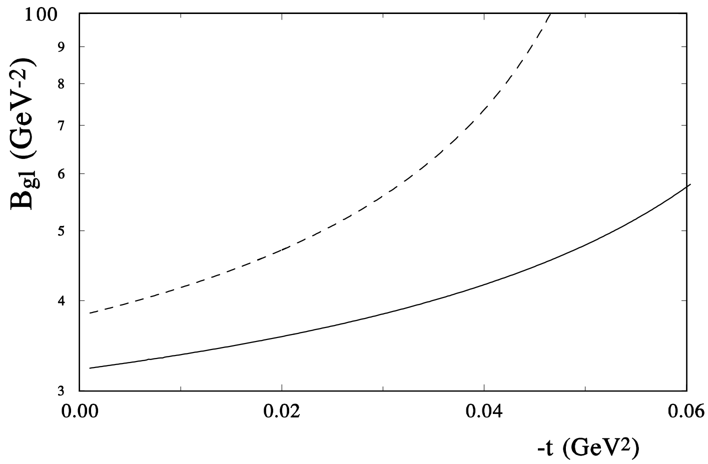
2.5
2.1
1.7
1.2
0.8
0.4
0.0
Δ_R, GeV-4
^{12}C
0.010
0.015
0.020
0.025
0.030
0.035
-t GeV2

Fig.4



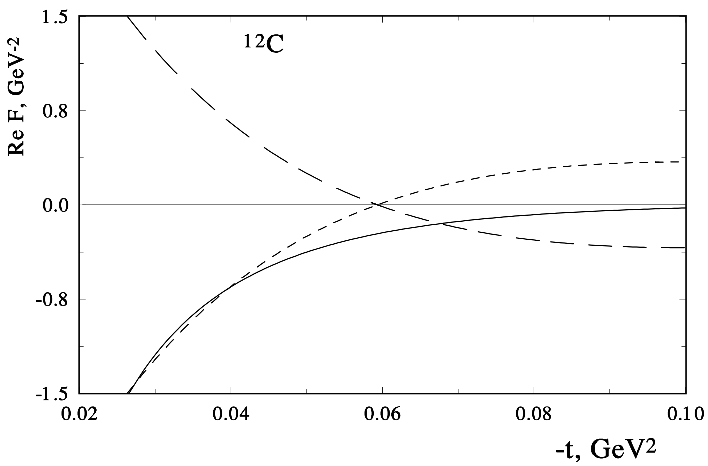
2.0
1.5
1.0
0.5
0.0
Δ_R, GeV-4
^{28}Si
0.010
0.015
0.020
0.025
0.030
0.035
-t, GeV2

Fig.5



100
9
8
7
6
5
4
3
B_{gl} (GeV-2)
0.00
0.02
0.04
0.06
-t (GeV2)

Fig.6



1.5
0.8
0.0
-0.8
-1.5
Re F, GeV-2
12C
0.02
0.04
0.06
0.08
0.10
-t, GeV2

Fig.7

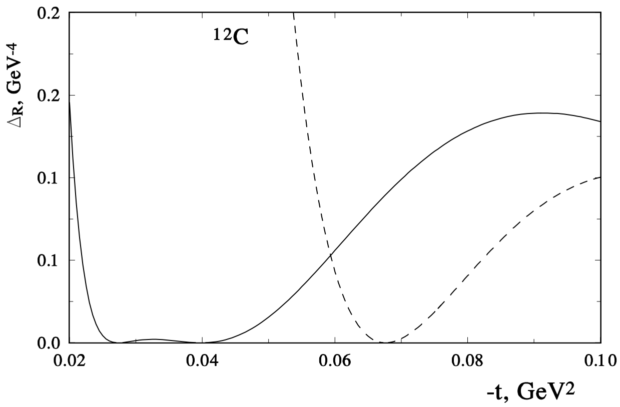

12C
ΔR, GeV-4
0.2
0.2
0.1
0.1
0.0
0.02
0.04
0.06
0.08
0.10
-t, GeV2

Fig.8 a

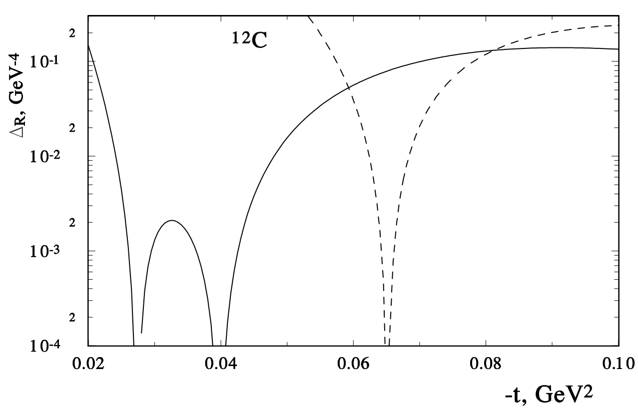

12C
ΔR, GeV-4
10-1
10-2
10-3
10-4
0.02
0.04
0.06
0.08
0.10
-t, GeV2

Fig.8 b